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Miyata

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(54) LIQUID-JET HEAD AND LIQUID-JET APPARATUS

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(51) **Int. Cl.**^{7} **B41J 2/045**
(52) **U.S. Cl.** **347/70**
(58) **Field of Search** 347/68, 70, 71

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(57) **ABSTRACT**

Disclosed are a liquid-jet recording head and a liquid-jet recording apparatus, which are capable of retaining a fine liquid ejecting characteristic and obtaining a stable liquid ejecting characteristic. The liquid-jet recording head, which is provided with a passage-forming substrate formed with pressure generating chambers **12** to communicate with nozzle orifices, and piezoelectric elements provided on one side of the passage-forming substrate through a vibration plate to generate pressure changes inside the pressure generating chambers, includes an insulation layer continuously provided at least in a region opposing to the vicinity of longitudinal end portions of the piezoelectric elements along a direction of arrangement of the piezoelectric elements, the insulation layer also having a penetrated portion in a region opposing to a common electrode provided in common to the plurality of piezoelectric elements, and a connective wiring layer continuously provided on the insulation layer to be electrically connected to the common electrode via the penetrated portion. Accordingly, a resistance value of the common electrode is substantially reduced.

13 Claims, 10 Drawing Sheets

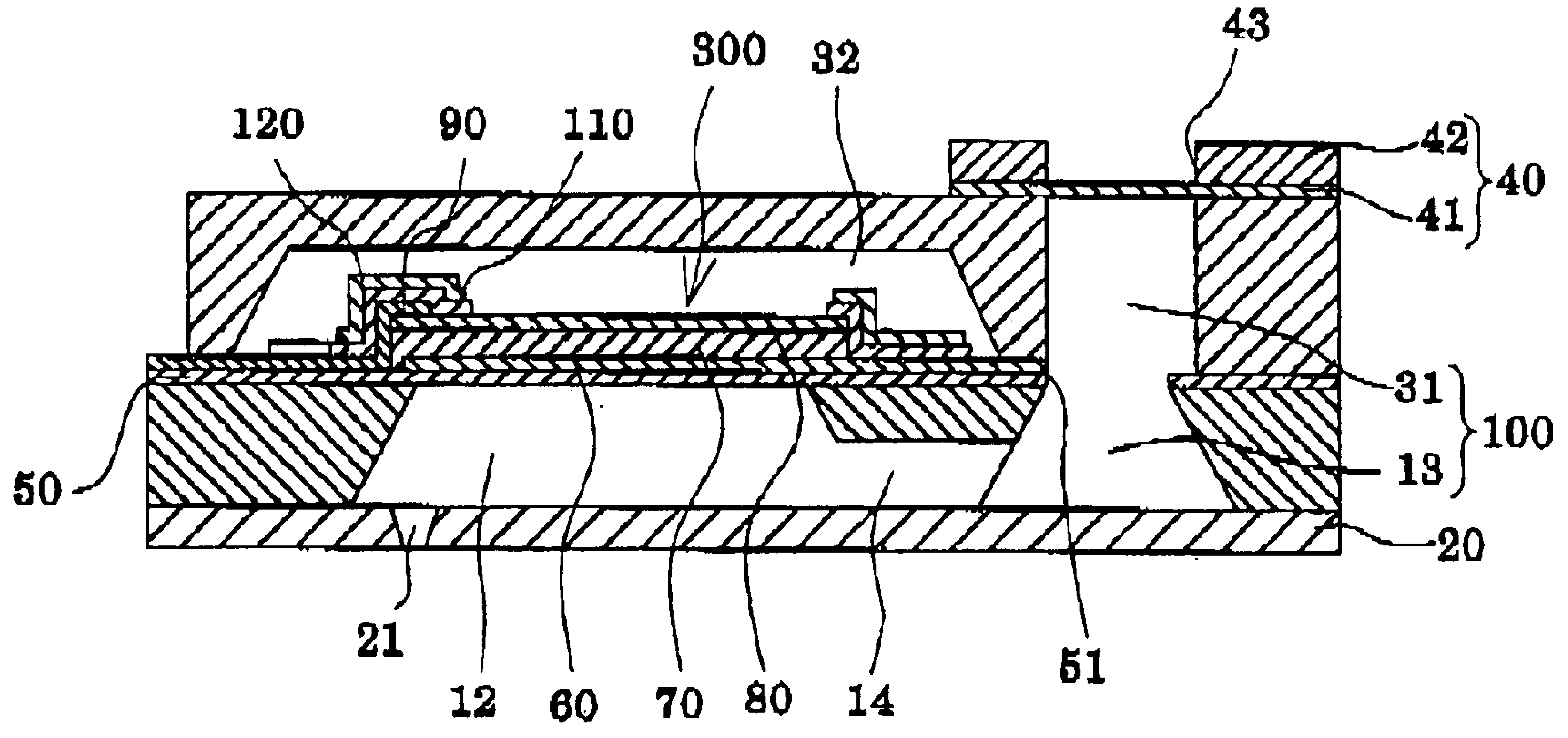

FIG.1

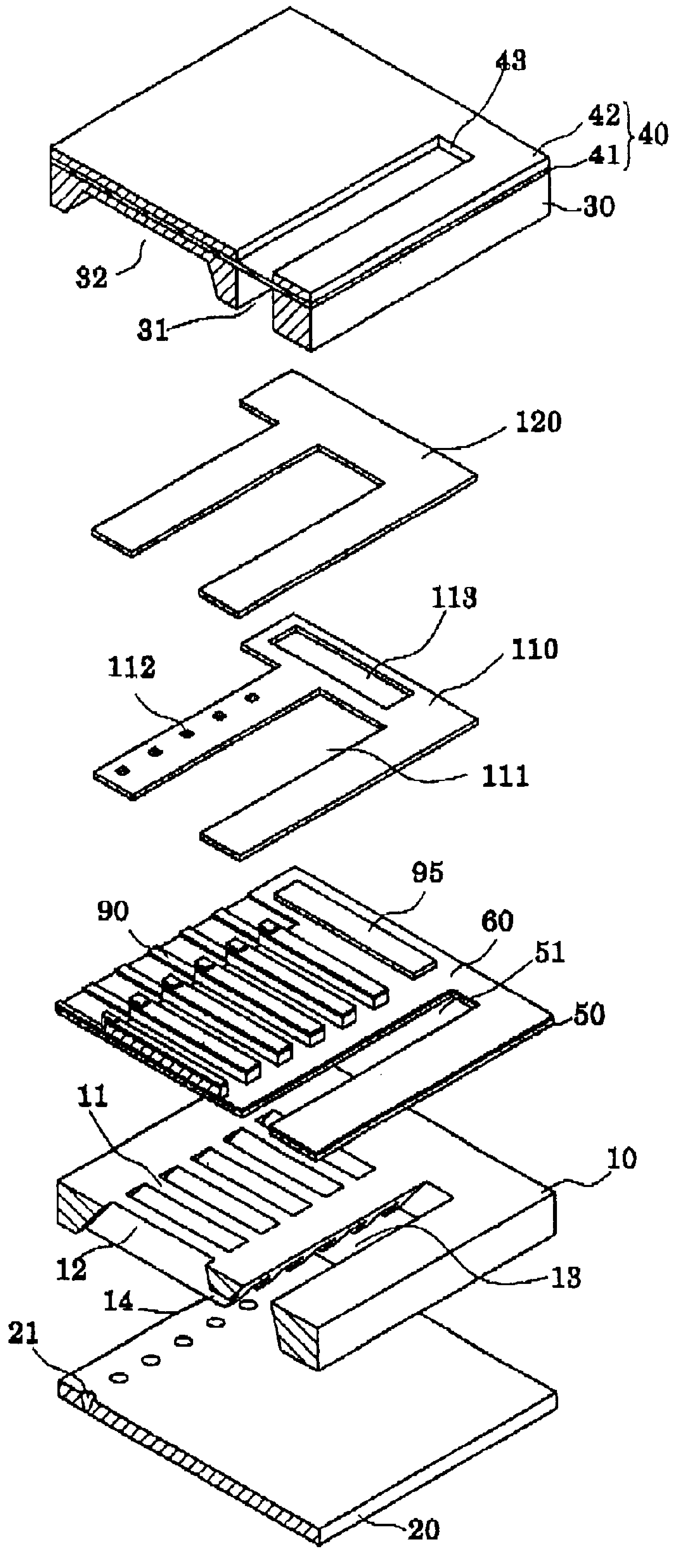
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FIG.2A

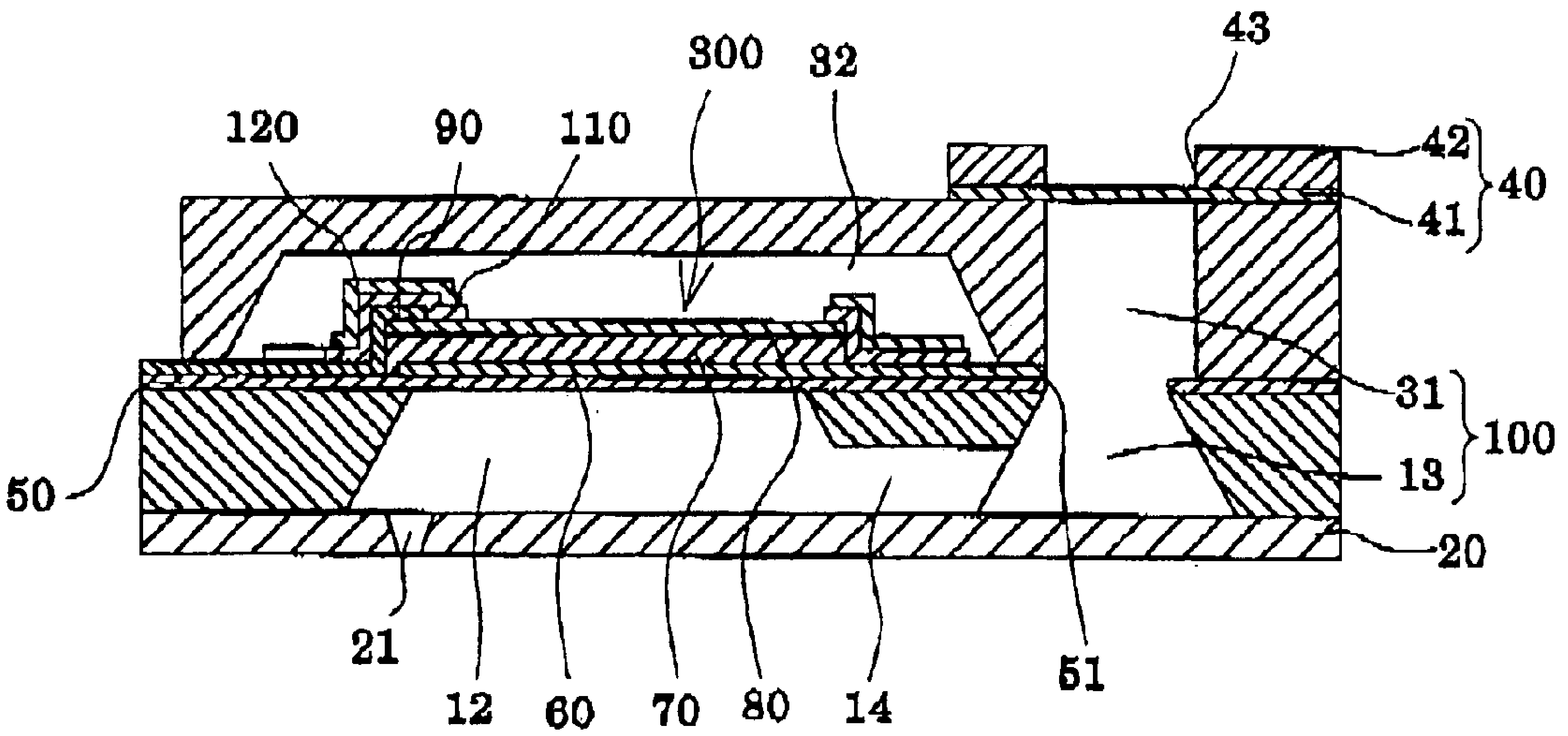
300
32
43
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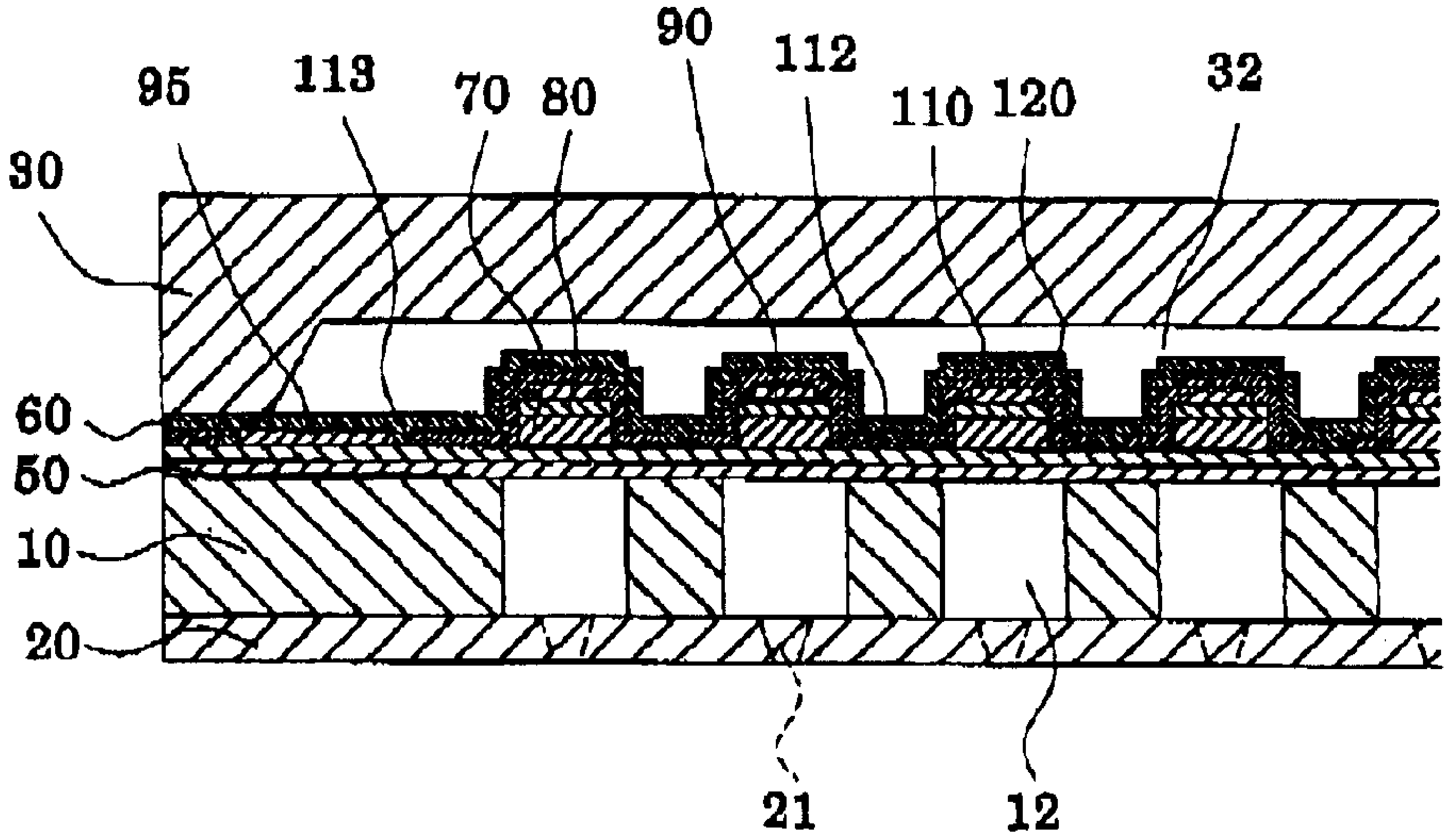
FIG.2B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112
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80
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20
21
12

FIG.3

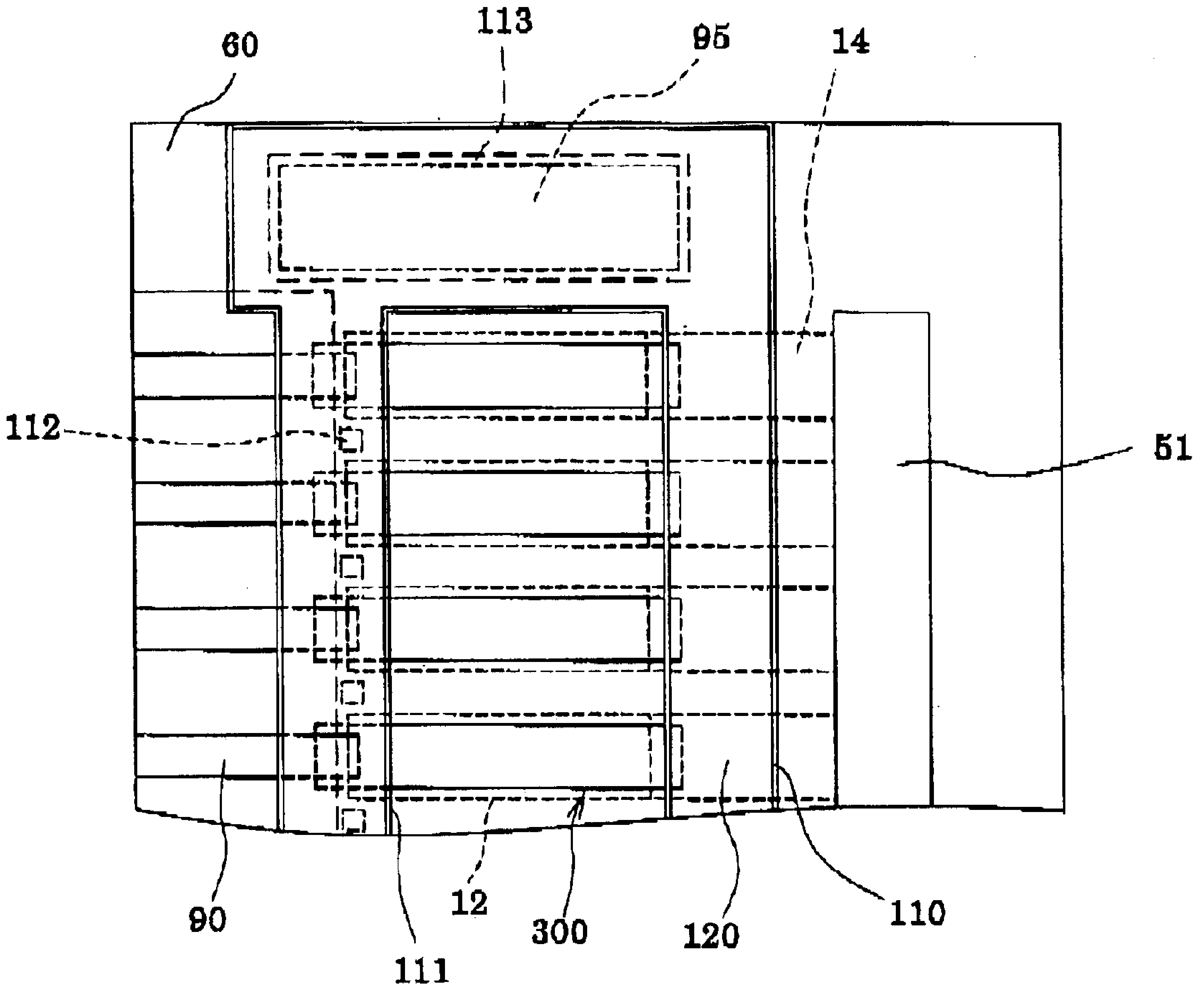


FIG.4

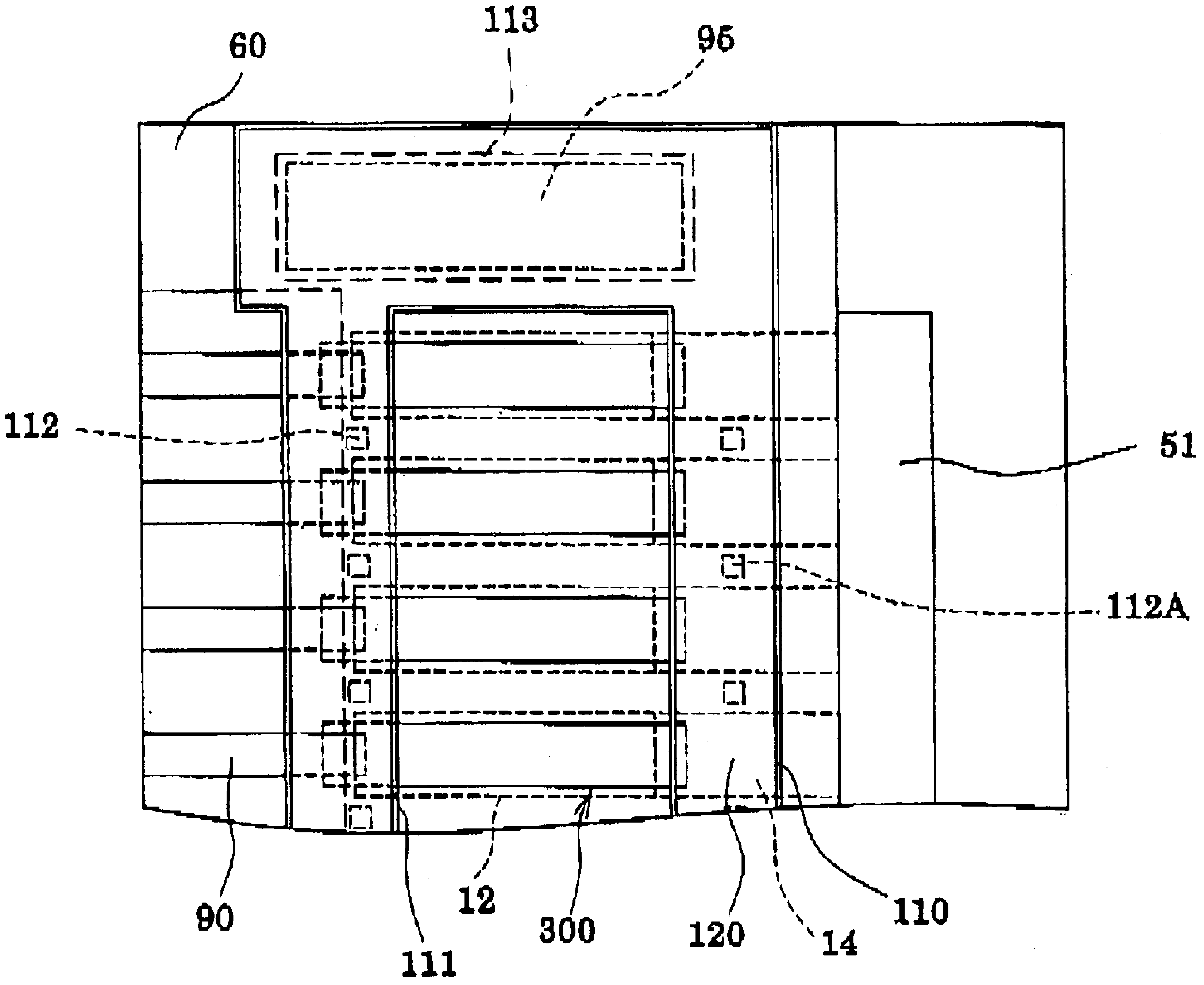


FIG.5

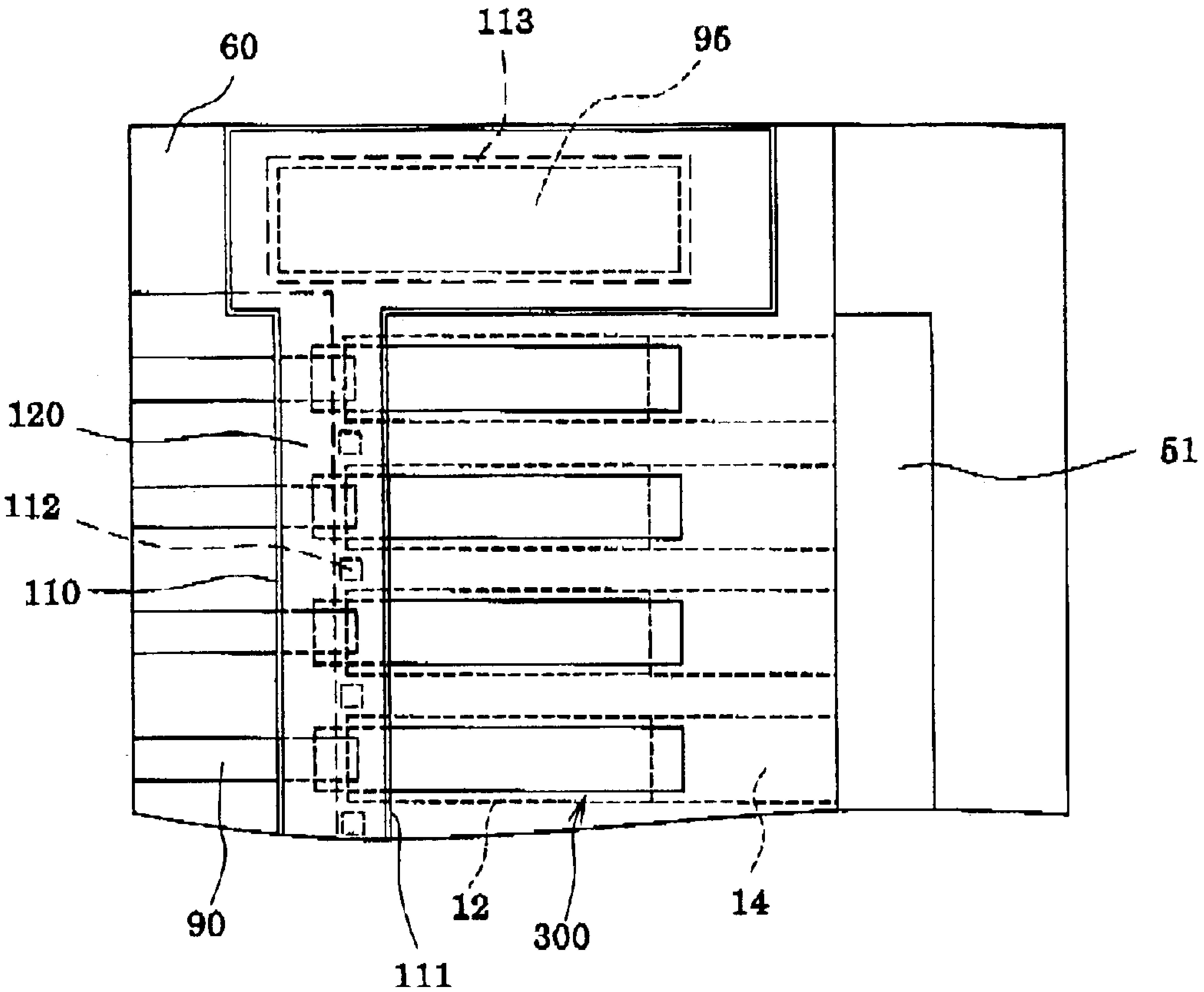


FIG.6

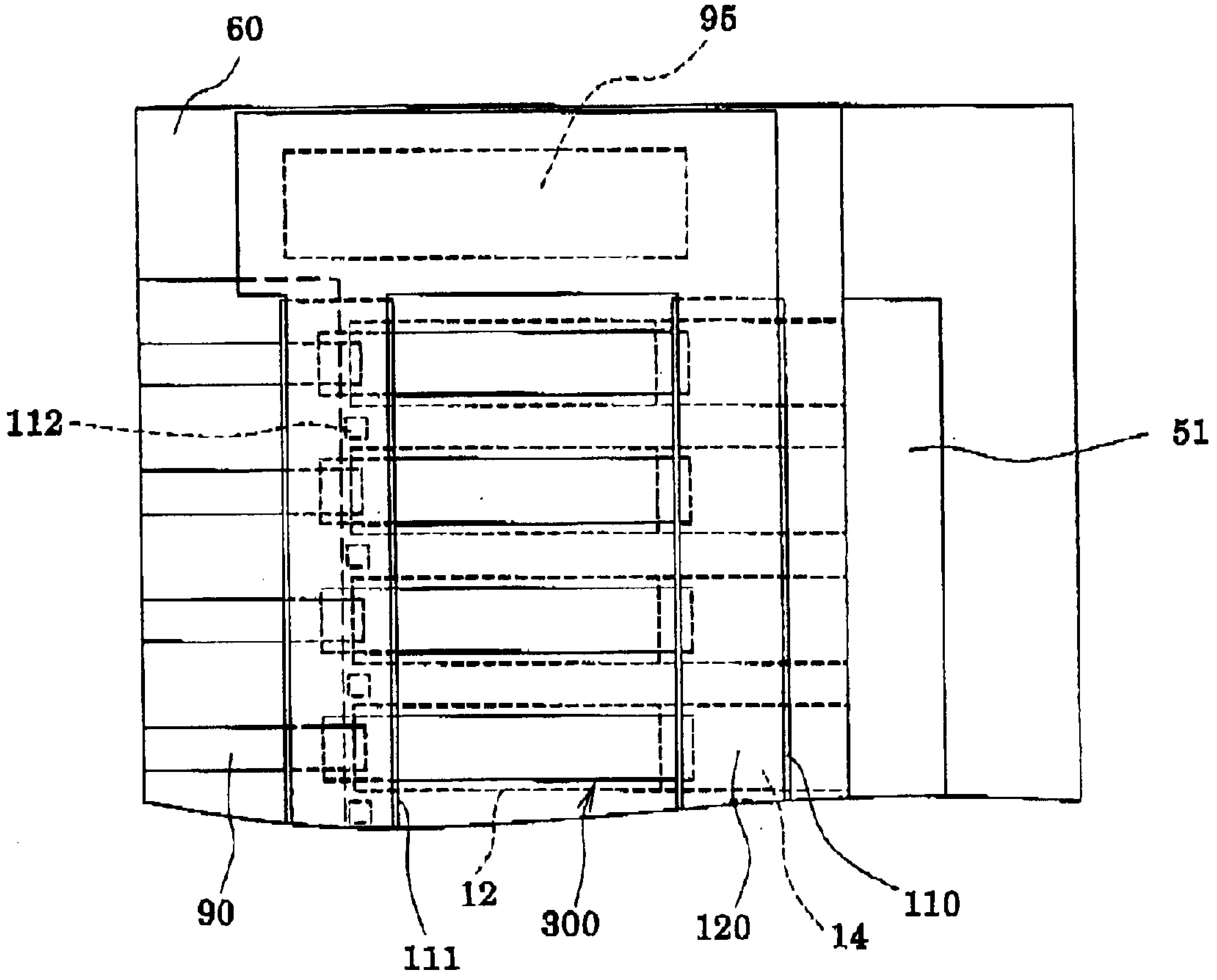


FIG.7A

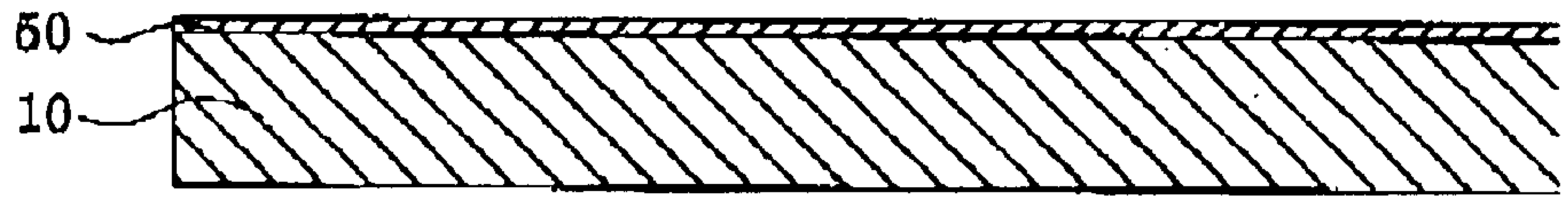


FIG.7B

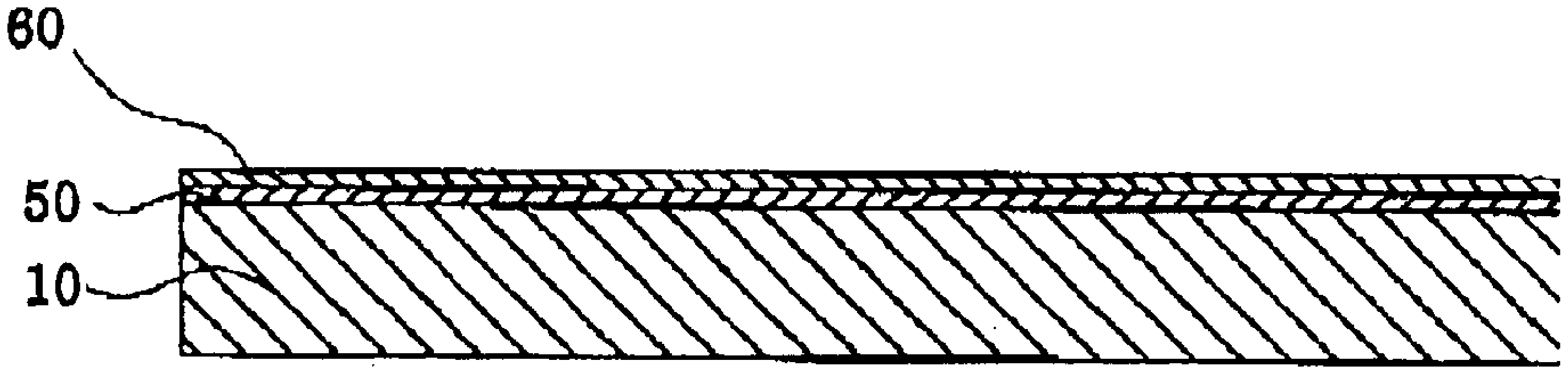


FIG.7C

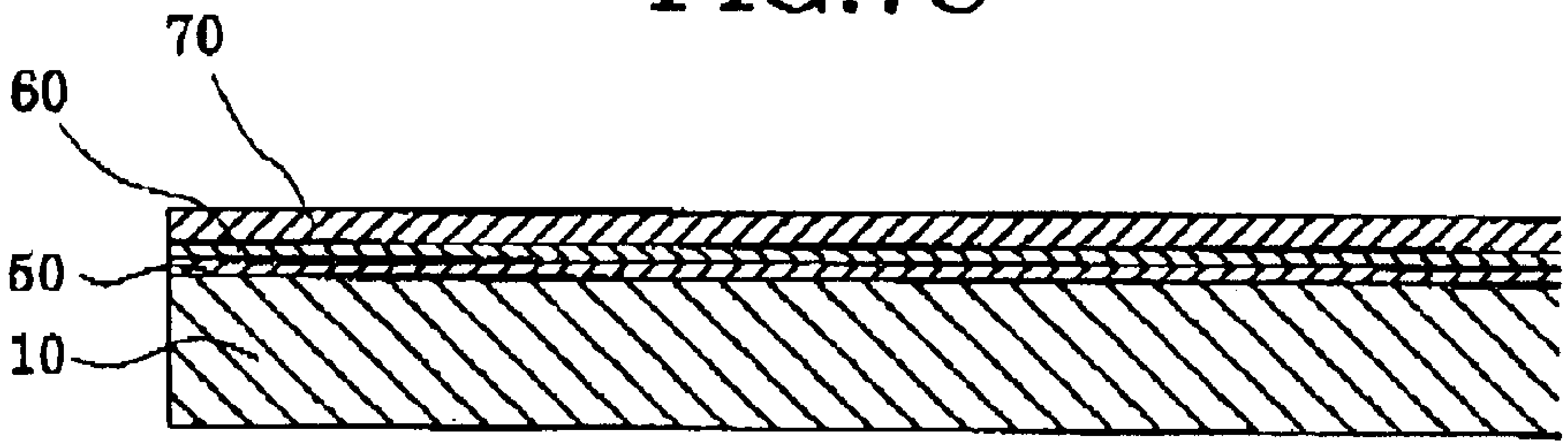


FIG.7D

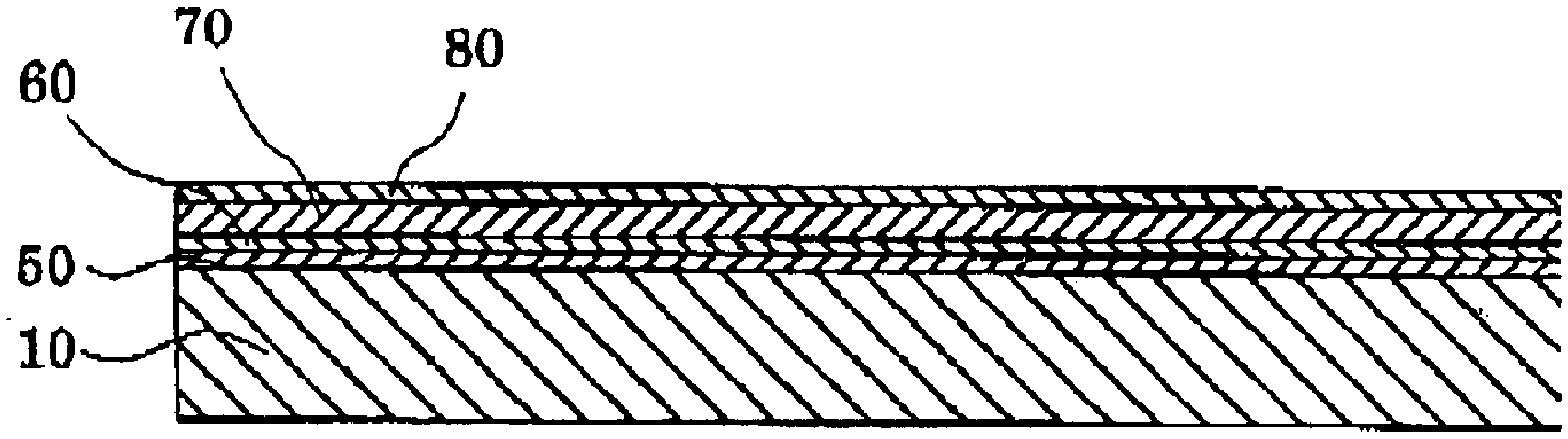


FIG.7E

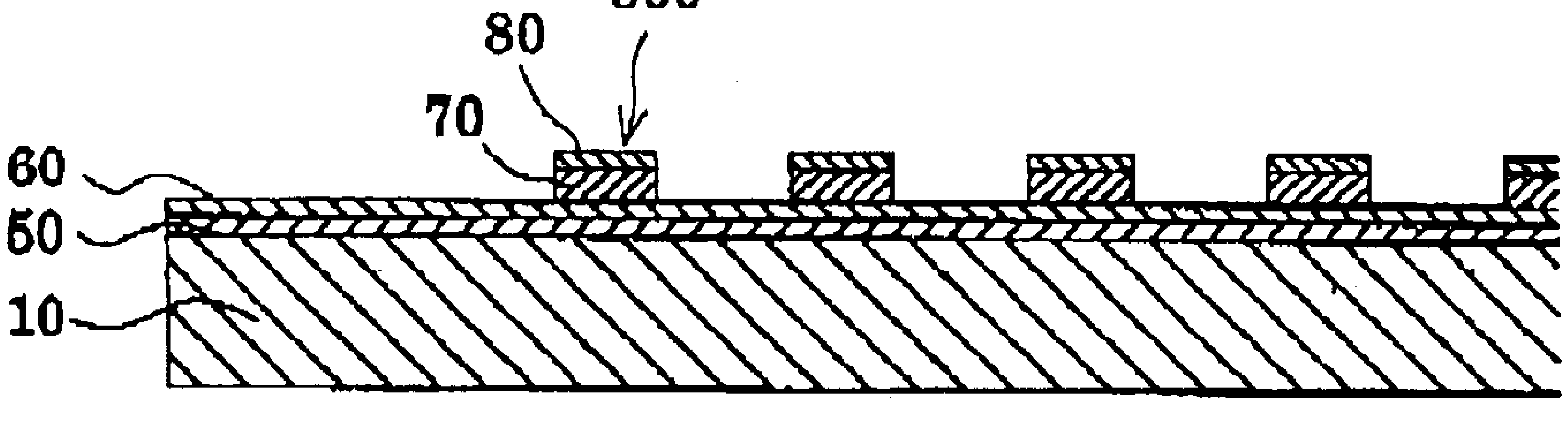


FIG.8A

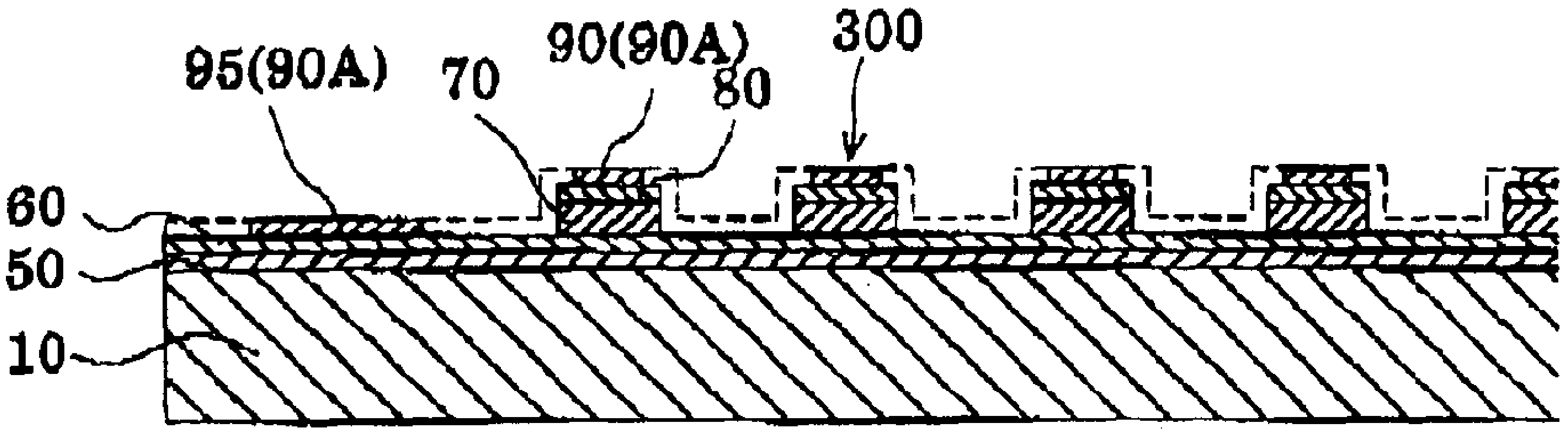


FIG.8B

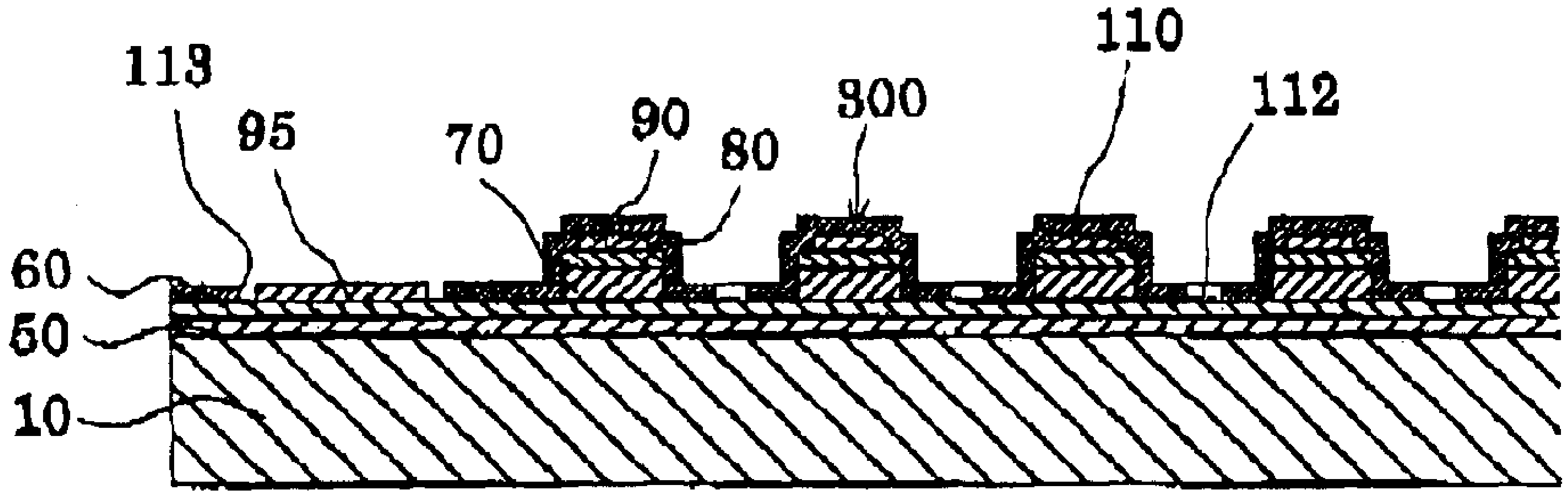


FIG.8C

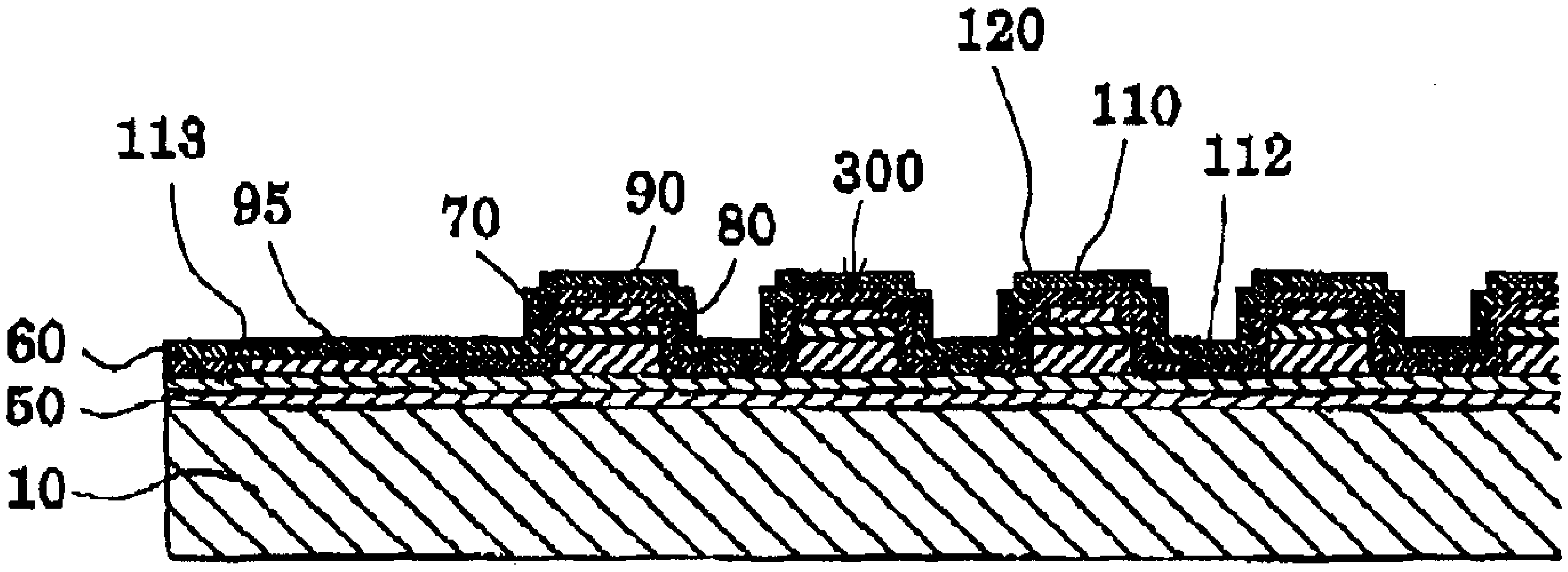


FIG.8D

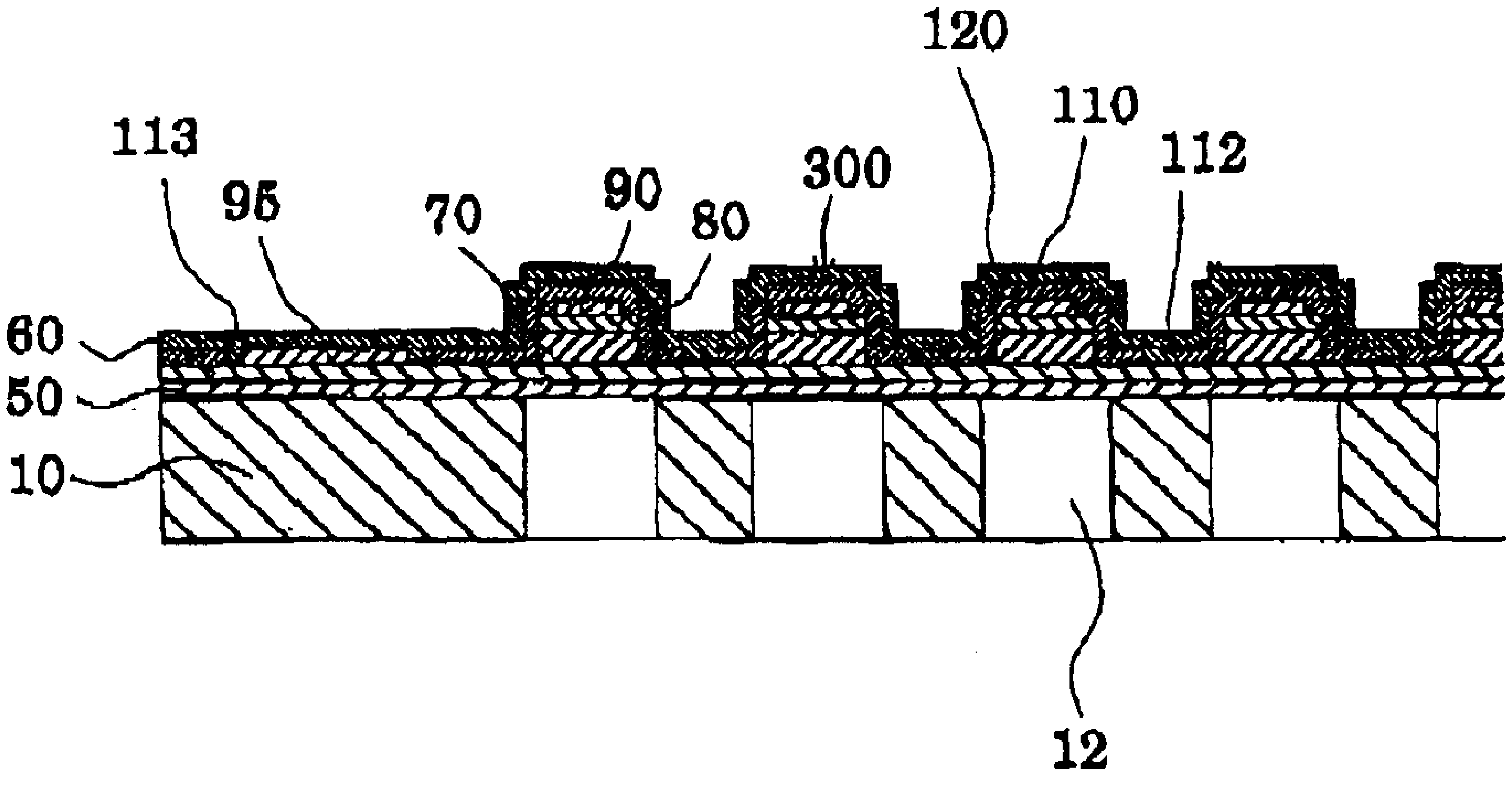


FIG.9A

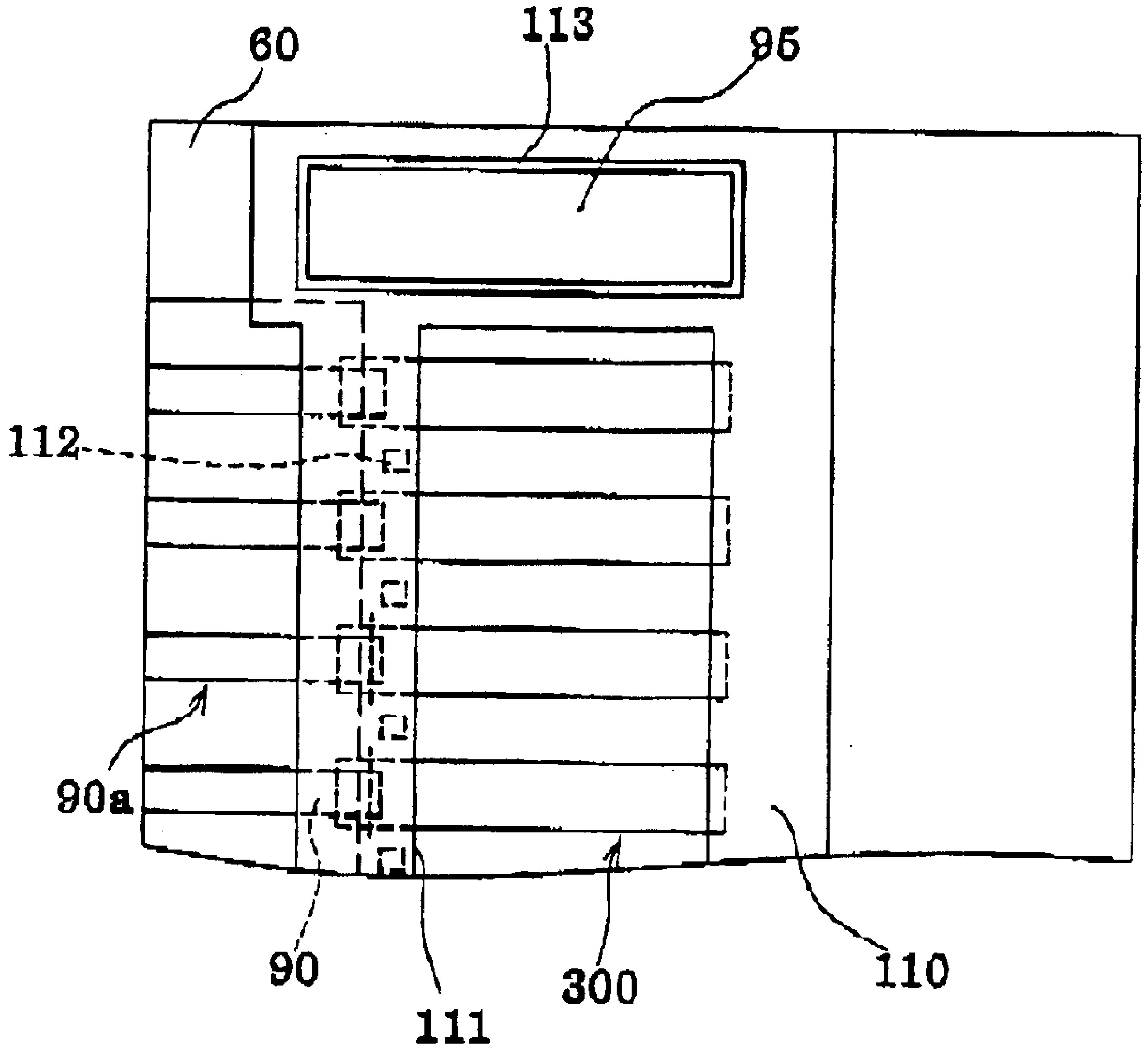

60
113
95
112
90a
90
111
300
110

FIG.9B

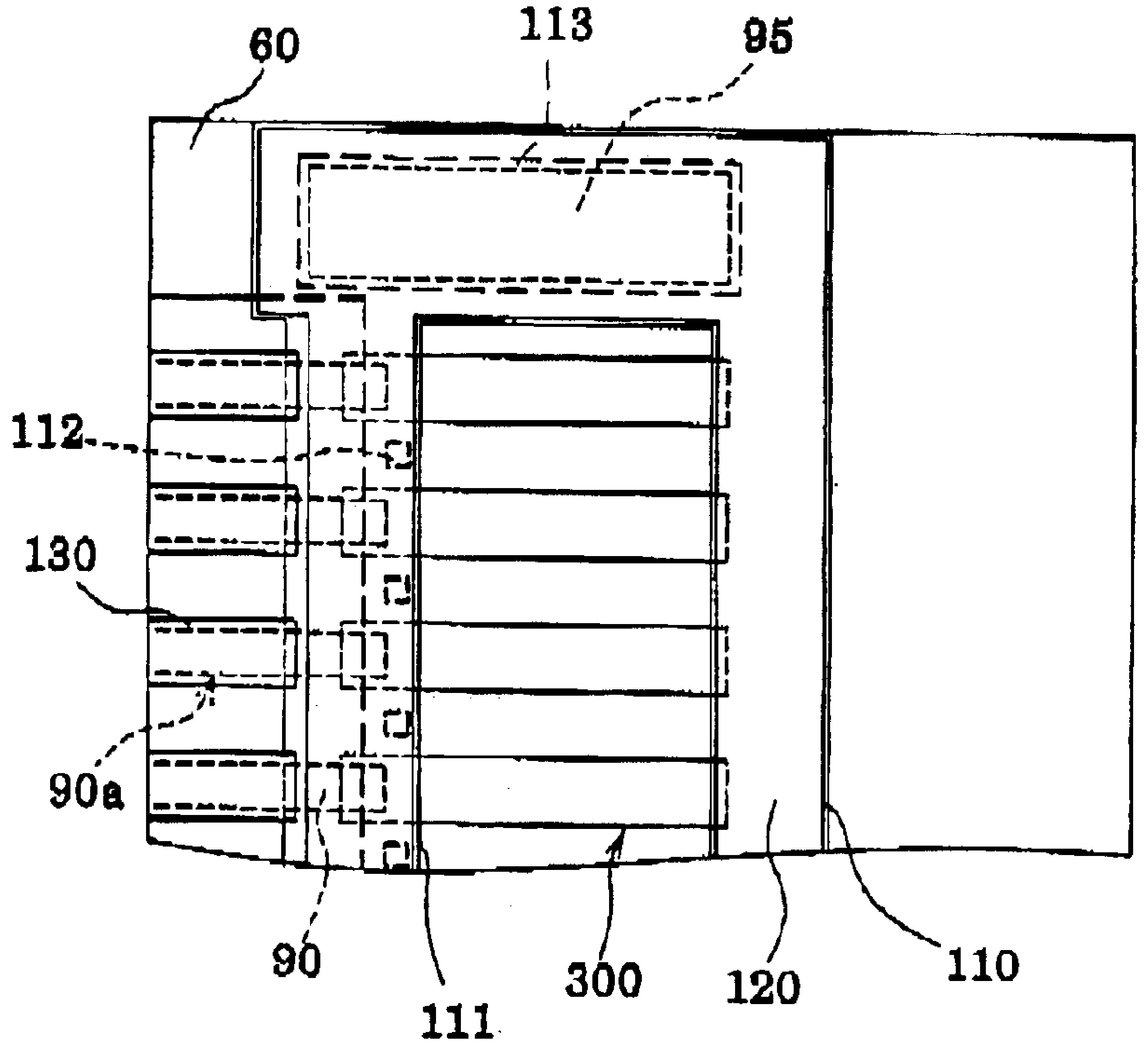
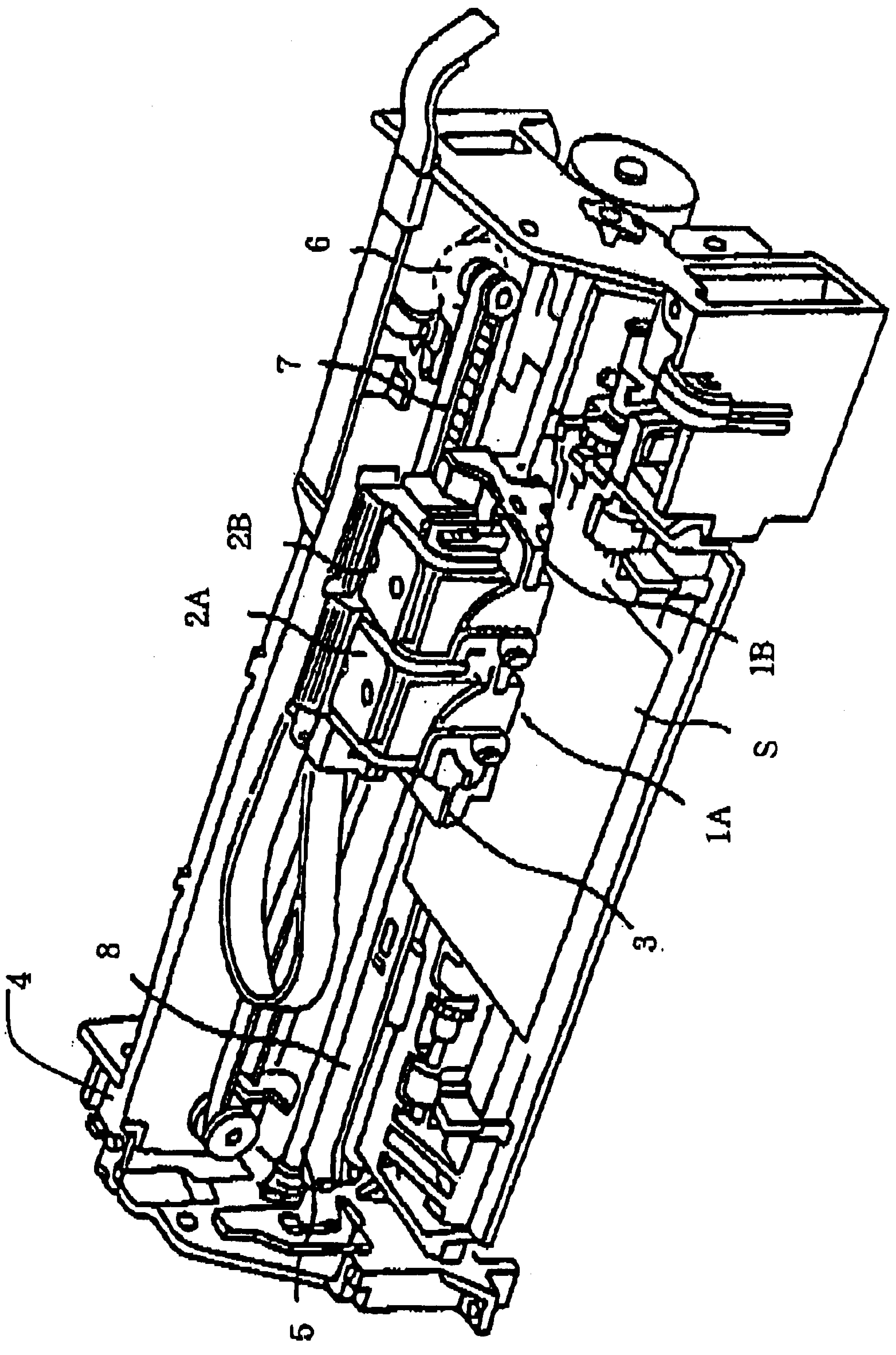

60
113
95
112
130
90a
90
111
300
120
110

FIG.10



LIQUID-JET HEAD AND LIQUID-JET APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an liquid-jet recording head and an liquid-jet recording apparatus, in which part of a pressure generating chamber to communicate with a nozzle orifice for ejecting liquid droplets is composed of a vibration plate and a piezoelectric element is formed on a surface of this vibration plate so as to cause ejecting of liquid droplets by displacement of the piezoelectric element. More particularly, the present invention relates to an ink-jet recording head that ejects ink as the liquid and to an ink-jet recording apparatus.

2. Description of the Prior Art

An ink-jet recording head, in which part of a pressure generating chamber to communicate with a nozzle orifice for ejecting ink droplets is composed of a vibration plate so as to cause ejecting of ink droplets out of the nozzle orifice by displacing this vibration plate with a piezoelectric element and thereby pressurizing the ink in the pressure generating chamber, has two types that are already in practical use, namely, one using a piezoelectric actuator of a longitudinal vibration mode which expands and contracts in an axial direction of a piezoelectric element, and one using a piezoelectric actuator of a flexure vibration mode.

The former one enables fabrication of a head suitable for high-density printing because the volume of the pressure generating chamber is made variable by allowing an end surface of the piezoelectric element to abut on a vibration plate. On the other hand, the former one has a problem that the fabrication process becomes complicated since a difficult process of carving the piezoelectric elements into comb-teeth shapes so as to be aligned with an arrangement pitch of the nozzle orifices, and an operation of positioning and fixing the carved piezoelectric elements onto the pressure generating chambers are required.

On the contrary, the latter one enables formation of the piezoelectric elements on the vibration plates by a relatively simple process of attaching a green sheet made of a piezoelectric material so as to agree with the shapes of the pressure generating chambers and then by baking the green sheet. However, the latter one has a problem that a high-density arrangement becomes difficult because a certain degree of area is required to utilize flexure vibration therein.

Meanwhile, in order to solve the inconvenience of the latter recording head, there is proposed a technology in which a uniform piezoelectric layer is formed over the entire surface of the vibration plate by use of a film-forming technology and this piezoelectric layer is carved into shapes corresponding to pressure generating chambers by a lithography method to form piezoelectric elements individually for the respective pressure generating chambers (refer to, for example, Japanese Patent Laid-Open No. 5(1993)-286131).

According to this technology, an operation of attaching piezoelectric elements to a vibration plate becomes unnecessary. Therefore, the technology provides not only a capability of forming the piezoelectric elements in high density by use of the accurate yet simple technique called the lithography method, but also provides an advantage that high-speed driving can be achieved by virtue of reducing the thickness of the piezoelectric element.

However, in such an ink-jet recording head having piezoelectric elements arranged in high density, one of electrodes (a common electrode) of each piezoelectric element is provided in common to a plurality of piezoelectric elements. Accordingly, if many piezoelectric elements are driven simultaneously to eject many ink droplets at one time, there occurs a problem that a voltage drop arises and the amount of displacement of the piezoelectric elements becomes unstable, whereby an ink ejecting characteristic is deteriorated.

Such a problem may be solved by increasing the thickness of the common electrode of the piezoelectric elements. However, since this common electrode includes part of the vibration plate, the amount of displacement of the vibration plate drops due to the drive of the piezoelectric elements. Alternatively, this problem may be solved by increasing the area of the common electrode. However, the size of the head is increased in this case.

Moreover, the electrodes of the piezoelectric elements formed of thin films have relatively high resistance values because of the films are thin. Therefore, the problems as stated above are very likely to occur.

Note that such a problem as described above needless to say occurs in other liquid-jet heads ejecting liquids other than ink, similarly to the ink-jet recording head ejecting ink.

SUMMARY OF THE INVENTION

In consideration of the foregoing circumstances, it is an object of the present invention to provide a liquid-jet recording head and a liquid-jet recording apparatus, which are capable of retaining a fine liquid ejecting characteristic and obtaining a stable liquid ejecting characteristic.

A first aspect of the present invention for attaining the foregoing object is a liquid-jet recording head having a passage-forming substrate in which pressure generating chambers to communicate with nozzle orifices is formed, and piezoelectric elements provided on one side of the passage-forming substrate through a vibration plate so as to generate pressure changes inside the pressure generating chambers. Here, the liquid-jet recording head includes: an insulation layer which is continuously provided at least in a region opposing to the vicinity of longitudinal end portions of the piezoelectric elements along a direction of arrangement of the piezoelectric elements, the insulation layer also having a penetrated portion in a region opposing to a common electrode provided in common to the plurality of piezoelectric elements; and a connective wiring layer which is continuously provided on the insulation layer to be electrically connected to the common electrode through the penetrated portion.

In the first aspect, a resistance value of the common electrode is substantially reduced by the connective wiring layer. Accordingly, a voltage drop in the event of driving the piezoelectric element is prevented, and a liquid ejecting characteristic is always retained favorably. Moreover, providing the insulation layer allows continuous formation of the connective wiring layer in the region opposing to the piezoelectric elements. Therefore, it is possible to form the connective wiring layer in a desired size without increasing the size of the head.

A second aspect of the present invention is the liquid-jet recording head according to the first aspect, in which the penetrated portions are provided on the insulation layer in regions opposing to compartment walls partitioning the pressure generating chambers, respectively.

In the second aspect, the virtual resistance value of the common electrode becomes approximately uniform as a whole because the common electrode and the connective wiring layer are electrically connected to each other with a given interval. Therefore, unevenness in the liquid ejecting characteristics among the nozzle orifices is prevented.

A third aspect of the present invention is the liquid-jet recording head according to any one of the first and the second aspects, in which the insulation layer in a region opposing to the pressure generating chamber is removed.

In the third aspect, displacement of the vibration plate upon driving the piezoelectric element is not blocked by the insulation layer, and the liquid ejecting characteristic is retained favorably.

A fourth aspect of the present invention is the liquid-jet recording head according to any one of the first to third aspects, in which an extraction electrode which is drawn out of an individual electrode of the piezoelectric element extends to the vicinity of an end portion of the passage-forming substrate, and at least a position close to a tip portion of the extraction electrode includes an exposed portion where a surface is exposed by removing the insulation layer and the connective wiring layer.

In the fourth aspect, each extraction electrode is electrically connected to a driver IC for driving the piezoelectric element at this exposed portion.

A fifth aspect of the present invention is the liquid-jet recording head according to the fourth aspect, in which the exposed portion of the extraction electrode is made of the same layer as the connective wiring layer and is electrically connected to an independent wiring layer respectively which is independent of the connective wiring layer.

In the fifth aspect, the liquid ejecting characteristic becomes certainly more stable because the resistance value of each extraction electrode is substantially reduced.

A sixth aspect of the present invention is the liquid-jet recording head according to the fifth aspect, in which the exposed portion of the extraction electrode is covered with the independent wiring layer.

In the sixth aspect, it is possible to prevent the extraction electrode from removal in the event of patterning the connective wiring layer.

A seventh aspect of the present invention is the liquid-jet recording head according to any one of the fourth to sixth aspects further including a laminated electrode layer which is provided on the common electrode in a region corresponding to the outside of an array of the pressure generating chambers, the laminated electrode layer being made of the same layer as the extraction electrode and provided independently of the extraction electrode. Here, the laminated electrode layer is electrically connected to the connective wiring layer.

In the seventh aspect, the resistance value of the common electrode can be further reduced by the laminated electrode layer, and the liquid ejecting characteristic becomes certainly more stable.

An eighth aspect of the present invention is the liquid-jet recording head according to any one of the first to seventh aspects, in which the insulation layer is made of photosensitive resin.

In the eighth aspect, it is possible to form the insulation layer relatively easily and with high accuracy.

A ninth aspect of the present invention is the liquid-jet recording head according to the eighth aspect, in which the photosensitive resin is polyimide resin.

In the ninth aspect, it is possible to form the insulation layer with high insulation property relatively easily by use of the given photosensitive resin.

A tenth aspect of the present invention is the liquid-jet recording head according to any one of the first to seventh aspects, in which the insulation layer is made of any one of fluorocarbon resin, silicone resin, epoxy resin, silicon oxide, silicon nitride, and tantalum oxide.

In the tenth aspect, it is possible to form the insulation layer with high insulation property relatively easily by use of the given material.

An eleventh aspect of the present invention is the liquid-jet recording head according to any one of the first to tenth aspects, in which the common electrode has a film thickness of 0.5 μm or less.

In the eleventh aspect, a favorable liquid ejecting characteristic is always obtained even if the film thickness of the common electrode is relatively thin.

A twelfth aspect of the present invention is the liquid-jet recording head according to any one of the first to eleventh aspects, in which the pressure generating chamber is formed on a single crystal silicon substrate by anisotropic etching, and the respective layers of the piezoelectric element are formed by a film-forming method and a lithography method.

In the twelfth aspect, it is possible to manufacture the liquid-jet recording heads with high-density nozzle orifices relatively easily and in high quantity.

A thirteenth aspect of the present invention is a liquid-jet recording apparatus including the liquid-jet recording head according to any one of the first to twelfth aspects.

In the thirteenth aspect, it is possible to realize the liquid-jet recording apparatus with a stable liquid ejecting characteristic and enhanced reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view of an ink-jet recording head according to a first embodiment of the present invention.

FIGS. **2**(*a*) and **2**(*b*) are cross-sectional views of the ink-jet recording head according to the first embodiment of the present invention.

FIG. **3** is a plan view showing a wiring structure of the ink-jet recording head according to the first embodiment.

FIG. **4** is a plan view showing a modified example of the wiring structure of the ink-jet recording head according to the first embodiment of the present invention.

FIG. **5** is a plan view showing another modified example of the wiring structure of the ink-jet recording head according to the first embodiment of the present invention.

FIG. **6** is a plan view showing still another modified example of the wiring structure of the ink-jet recording head according to the first embodiment of the present invention.

FIGS. **7**(*a*) to **7**(*e*) are cross-sectional views showing manufacturing process of the ink-jet recording head according to the first embodiment of the present invention.

FIGS. **8**(*a*) to **8**(*d*) are cross-sectional views showing the manufacturing process, of the ink-jet recording head according to the first embodiment of the present invention.

FIGS. **9**(*a*) and **9**(*b*) are plan views showing a modified example of the manufacturing process of the ink-jet recording head according to the present invention.

FIG. **10** is a schematic illustration of an ink-jet recording apparatus according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, the present invention will be described in detail based on embodiments.

(First Embodiment)

FIG. **1** is an exploded perspective view of an ink-jet recording head according to a first embodiment of the present invention. FIGS. **2**(*a*) and **2**(*b*) are cross-sectional views of FIG. **1**, and FIG. **3** is a plan view showing a wiring structure of the ink-jet recording head according to the first embodiment.

As illustrated therein, a passage-forming substrate **10** is made of a single crystal silicon substrate having a plane orientation (110) in this embodiment. On one surface thereof, a plurality of pressure generating chambers **12** formed by anisotropic etching are arranged side by side along a width direction thereof. Moreover, on the outside in the longitudinal direction of the pressure generating chambers **12**, there is formed a communicating portion **13** constituting part of a reservoir, which communicates with a reservoir portion **31** of a reservoir forming plate **30** to be described later and thereby includes a common ink chamber to the respective pressure generating chambers **12**. The communicating portion **13** communicates with a longitudinal end of each pressure generating chamber **12** respectively through an ink supply path **14**.

Moreover, one of the surfaces of this passage-forming substrate **10** includes an opening surface, and on the other surface there is formed an elastic film **50** in the thickness of 1 to 2 μm made of silicon dioxide being formed by thermal oxidation.

Here, anisotropic etching is performed by use of a difference in etching rates on the single crystal silicon substrate. For example, in this embodiment, anisotropic etching is performed by use of the following property that the single crystal silicon substrate is gradually eroded when immersed in an alkaline solution such as KOH, whereby there develop a first (111) plane being perpendicular to the (110) plane and a second (111) plane forming an angle of about 70 degrees with this first (111) plane and forming an angle of about 35 degrees with the (110) plane, and that the etching rate on the (111) planes is about $\frac{1}{180}$ as compared to the etching rate on the (110) plane. By adoption of such anisotropic etching, high-precision processing becomes feasible based on depth processing of a parallelogram shape formed by two first (111) planes and two oblique second (111) planes. Accordingly, it is possible to arrange the pressure generating chambers **12** in high density.

In this embodiment, long sides of each pressure generating chamber **12** are formed of the first (111) planes and short sides thereof are formed of the second (111) planes. This pressure generating chamber **12** is formed by etching so as to almost penetrate the passage-forming substrate **10** until reaching the elastic film **50**. Here, the elastic film **5** is hardly eroded by the alkaline solution for etching the single crystal silicon substrate. Moreover, each ink supply path **14** which communicates with one end of each pressure generating chamber **12** is formed shallower than the pressure generating chamber **12**, and thereby maintains constant passage resistance of the ink flowing into the pressure generating chamber **12**. In other words, the ink supply path **14** is formed by etching the single crystal silicon substrate halfway in the thickness direction (half-etching). Note that such half-etching is achieved by adjustment of etching time.

Here, regarding the thickness of the passage-forming substrate **10** to be formed with such pressure generating chambers **12** and the like, it is preferable that an optimal thickness is selected in accordance with the density of arranging the pressure generating chambers **12**. For example, in the case of arranging the pressure generating chambers **12** in line with some 180 dots per inch (180 dpi), the thickness of the passage-forming substrate **10** is preferably set to about 180 to 280 μm, or more preferably to about 220 μm. Meanwhile, in the case of arranging the pressure generating chambers **12** relatively in high density of some 360 dpi, for example, the thickness of the passage-forming substrate **10** is preferably set to 100 μm or below. In this manner, it is possible to increase the arrangement density while maintaining rigidity of compartment walls between adjacent pressure generating chambers **12**.

Moreover, a nozzle plate **20** is fixed to an opening surface side of the passage-forming substrate **10** with an adhesive agent or a thermowelding film. Here, the nozzle plate **20** includes nozzle orifices **21**, which are drilled to communicate with the respective pressure generating chambers **12** on an opposite side to the side where the respective pressure generating chambers **12** communicate with the ink supply paths **14**. Note that the nozzle plate **20** is made of glass ceramics, rust-proof steel or the like, which has a thickness in a range from 0.1 to 1 mm and a linear expansively from 2.5 to 4.5×10^{-6}/° C. at a temperature of 300° C. or below, for example. The nozzle plate **20** covers the entire surface of the passage-forming substrate **10** with one plane thereof, whereby the nozzle plate **20** also functions as a reinforcing plate for protecting the single crystal silicon substrate against impacts or external forces, Meanwhile, it is also possible to form the nozzle plate **20** by use of a material having a coefficient of thermal expansion almost the same as that of the passage-forming substrate **10**. In this case, degrees of deformation of the passage-forming substrate **10** and the nozzle plate **20** with heat become almost equivalent to each other. Accordingly, it is possible to join the both members easily by use of a thermosetting adhesive agent or the like.

Here, the size of the pressure generating chamber **12** for dispersing ink-droplet ejecting pressure to ink and the size of the nozzle orifice **21** for ejecting ink droplets are optimized in accordance with an amount of ink droplets to be ejected, an ejecting speed, and an ejecting frequency. For example, in the case of recording 360 dots of ink droplets per inch, the nozzle orifices **21** need to be formed accurately so as to have diameters of tens of micrometers.

Meanwhile, a lower electrode film **60** in a thickness of about 0.2 μm, for example, a piezoelectric layer **70** in a thickness of about 1 μm, for example, and an upper electrode film **80** in a thickness of about 0.1 μm, for example, are formed on the elastic film **50** provided on the opposite side to the opening surface of the passage-forming substrate **10** by lamination in accordance with a process to be described later, whereby a piezoelectric element **300** is included. Here, the piezoelectric element **300** refers to a portion including the lower electrode film **60**, the piezoelectric layer **70** and the upper electrode film **80**. In general, the piezoelectric element **300** is constituted by setting one of the electrodes thereof as a common electrode, while the other electrode and the piezoelectric layer **70** are patterned by each pressure generating chamber **12**. Moreover, a portion composed of one of the electrodes and the piezoelectric layer **70** thus patterned, the portion causing piezoelectric distortion upon application of voltage to the both electrodes, is hereinafter referred to as a piezoelectric active portion. In this embodiment, the lower electrode film **60** is defined as the common electrode of the piezoelectric element **300** and the upper electrode film **80** is defined as an individual electrode of the piezoelectric element **300**. However, there is no obstacle in inverting such definitions due to a reason attributable to drive circuits or wiring designs. In any case, a piezoelectric active portion will be formed on each pressure generating chamber. Furthermore, the piezoelectric element **300**, and a vibration plate to be displaced by the drive of the piezoelectric element **300** are hereinafter collectively referred to as a piezoelectric actuator.

Here, an extraction electrode **90** is connected to each upper electrode film **80** which is the individual electrode of the piezoelectric element **300**. Here, the extraction electrode **90** is made of gold (Au) and the like, for example, and extends from the vicinity of an end portion on the opposite side to the ink supply path **14** to the vicinity of an end portion of the passage-forming substrate **10**. Moreover, although it is not illustrated in the drawings, external wiring which leads to a driver circuit for driving the piezoelectric element **300** is connected to the vicinity of a tip portion of this extraction electrode **90**.

Meanwhile, the lower electrode film **60** which is the common electrode to the piezoelectric elements **300** is provided so as to extend continuously across the direction of arrangement of the pressure generating chambers **12**. The lower electrode film **60** is also patterned in the vicinity of an end portion on the opposite side to the ink supply paths **14** of the pressure generating chambers **12**. That is to say, in this embodiment, the lower electrode film **60** is removed only in an after-mentioned region of the passage-forming substrate **10** where the extraction electrodes **90** are extended, and is provided on the entire surface of the passage-forming substrate **10** in the remaining region.

Moreover, in this embodiment, a laminated electrode layer **95** is provided on the lower electrode film **60** in a region corresponding to the outside of an array of the pressure generating chambers **12**. Here, the laminated electrode layer **95** is made of the same layer as the extraction electrodes **90** but is independent of the extraction electrodes **90**.

In addition, an insulation layer **110** is provided in a region opposing to the vicinity of the longitudinal end portions of the piezoelectric elements **300**. Here, the insulation layer **110** is made of an insulating material and extends along the direction of arrangement of the piezoelectric elements **300**. For example, in this embodiment, the insulation layer **110** is provided continuously around the array of the pressure generating chambers **12**, and the region corresponding to the array of the pressure generating chambers **12** is formed as an opening portion **111**.

Moreover, a Connective wiring layer **120** made of a conductive material is continuously provided on this insulation layer **110**. This connective wiring layer **120** is electrically connected to the lower electrode film **60** via a plurality of penetrated portions **112** provided on the insulation layer **110**.

Here, it is preferable that the penetrated portions **112** to be provided on the insulation layer **110** are disposed at relatively even intervals. For example, in this embodiment, each penetrated portion **112** is provided in a region opposing to each compartment wall **11** of the insulation layer **110** which extends in the vicinity of the end portion on the extraction electrode **90** side of each piezoelectric element **300**. Although the size of the penetrated portion **112** is not particularly limited, however, it is preferably set to 20 μm or below.

Moreover, a penetrated portion **113** is also provided in a region opposing to the outside of the array of the pressure generating chambers **12**, i.e. the region opposing to the laminated electrode layer **95** provided on the lower electrode film **60**. The laminated electrode layer **95** (the lower electrode film **60**) is electrically connected to the connective wiring layer **120** via this penetrated portion **113** as well.

In this way, a resistance value of the lower electrode film **60** is substantially reduced by electrically connecting the connective wiring layer **120** to the lower electrode film **60** which is the common electrode of the piezoelectric element **300**. Similarly, the resistance value of the lower electrode film **60** is substantially reduced also by providing the laminated electrode layer **95** on the lower electrode film **60**. Therefore, a voltage drop does not occur even it many piezoelectric elements are driven simultaneously, whereby a favorable and stable ink ejecting characteristic is always obtained.

Moreover, since the connective wiring layer **120** is provided in the region opposing to the end portion of the piezoelectric element **300** via the insulation layer **110**, it is not necessary to reserve a space for providing the connective wiring layer **120**. Therefore, it is possible to stabilize the ink ejecting characteristic without the increase of the size of the head.

Furthermore, since the connective wiring layer **120** are electrically connected to the lower electrode film **60** via the plurality of penetrated portions **112** and **113** on the insulation layer **110**, the resistance values at various portions on the lower electrode film **60** are made approximately equal, whereby an amount of displacement of the vibration plate by the drive of each piezoelectric element **300** is stabilized. In this way, it is possible to equalize the ink ejecting characteristics of the ink which is ejected from the respective nozzle orifices.

Moreover, in this embodiment, since the insulation layer **110** and the connective wiring layer **120** are provided outside the region opposing to the array of the pressure generating chambers **12**, displacement of the vibration plate is not inhibited by the connective wiring layer **120**, Therefore, the connective wiring-layer **120** can be made relatively thicker, whereby the resistance value of the lower electrode film **60** can be surely reduced.

Note that each penetrated portion **112** is provided in the region opposing to each compartment wall **11** of the insulation layer **110** which extends to the vicinity of the end portions on the side of the extraction electrodes **90** of the respective piezoelectric elements **300** in this embodiment. However, the number and positions of the penetrated portions **112** are not particularly limited. For example, as shown in FIG. **4**, penetrated portions **112**A may be provided at given intervals on the insulation layer **110** extended to the vicinity of end portions of the piezoelectric elements **300** on the opposite side to the extraction electrodes **90**.

Moreover, the region for providing the connective wiring layer **120** is not particularly limited, either. The region for providing the connective wiring layer **120** should be appropriately decided in consideration of conditions such as the resistance value of the lower electrode film **60**. For example, as shown in FIG. **5**, the connective wiring layer **120** may be provided only in the region opposing to the vicinity of the end portions on the side of the extraction electrodes **90** of the piezoelectric elements **300** and in the region opposing to the outside of the array of the pressure generating chambers **12**.

Furthermore, the insulation layer **110** is provided to prevent short circuits between the lower electrode film **60** and the upper electrode film **80**, in other words, to prevent electrical contact of the connective wiring layer **120** to the upper electrode film **80** and the extraction electrode **90**. Therefore, although the insulation layer **110** is also provided in the region opposing to the outside of the array of the pressure generating chambers **12** in this embodiment, it is satisfactory if the insulation layer **110** is provided at least in the region corresponding to the vicinity of the longitudinal end portions of the piezoelectric elements **300** as shown in FIG. **6**.

Note that a reservoir-forming plate **30**, which includes a reservoir portion **31** that includes at least part of a reservoir **100** serving as a common ink chamber to the respective pressure generating chambers **12**, is joined to the passage-forming substrate on the side of the piezoelectric elements **300**. In this embodiment, this reservoir portion **31** penetrates the reservoir-forming plate **30** in the thickness direction and is formed across the width direction of the pressure generating chambers **12**. Moreover, the reservoir-forming plate **30** communicates with the communicating portion **13** of the passage-forming substrate **10** via a penetrated hole **51** provided by penetrating the elastic film **50**, thereby constituting the reservoir **100** which serves as the common ink chamber to the respective pressure generating chambers **12**.

As for the reservoir-forming plate **30**, it is preferable to use a material having approximately the same coefficient of thermal expansion as that of the passage-forming substrate **10** such as glass, a ceramic material or the like. In this embodiment, the reservoir-forming plate **30** is formed by use of a single crystal silicon substrate, which is the same material as the passage-forming substrate **10**.

Moreover, a piezoelectric element holding portion **32** is provided in a region opposing to the piezoelectric elements **300** of the reservoir-forming plate **30** in the state of securing a space to the extent not to interfere with movement of the piezoelectric elements **300**. The piezoelectric elements **300** are tightly sealed inside this piezoelectric element holding portion **32**.

Moreover, a compliance plate **40** composed of a sealing film **41** and a fixing plate **42** is joined to the reservoir-forming plate **30**. Here, the sealing film **41** is made of a material having low rigidity and high flexibility (such as a polyphenylene sulfide (PPS) film in a thickness of 6 μm). One side of the reservoir portion **31** is sealed by this sealing film **41**. Meanwhile, the fixing plate **42** is made of a hard material of metal or the like (such as stainless steel (SUS) in a thickness of 30 μm). A region of the fixing plate **42** opposing to the reservoir **100** is completely removed in the thickness direction so as to include an opening portion **43**. Accordingly, one side of the reservoir **100** is sealed only by the flexible sealing film **41**.

The ink-jet recording head in this embodiment intakes ink from unillustrated external ink supplying means, whereby the ink is filled to the inside ranging from the reservoir **100** to the nozzle orifices **21**. Thereafter, voltage is applied between the lower electrode film **60** and the upper electrode film **80** corresponding to each pressure generating chamber **12** via external wiring in accordance with a recording signal from an unillustrated external driver circuit, whereby the elastic film **50**, the lower electrode film **60**, and the piezoelectric layer **70** are subjected to flexure deformation. In this way, pressure inside each of the pressure generating chambers **12** is increased and the ink droplets are thereby ejected from the nozzle orifice **21**.

Now, description will be made regarding an example of a method of manufacturing the ink-jet recording head of this embodiment with reference to FIG. **7**(*a*) to FIG. **8**(*d*). Note that FIG. **7**(*a*) to FIG. **8**(*d*) are cross-sectional views showing part of the pressure generating chamber **12** along the width direction thereof.

First, as shown in FIG. **7**(*a*), a single crystal silicon substrate to be formed into the passage-forming substrate **10** is subjected to thermal oxidation in a diffusion furnace at a temperature of about 1100° C., thus forming the elastic film **50** made of silicon dioxide.

Next, as shown in FIG. **7**(*b*), the lower electrode film **60** is formed on the entire surface of the elastic film **50**, and then the lower electrode film **60** is patterned to form an entire pattern. Here, platinum (Pt) or the like is suitable for the material of this lower electrode film **60**. It is because the after-mentioned piezoelectric layer **70** to be formed into a film by a sputtering method or a sol-gel method needs to be crystallized at a temperature in a range from about 600° C. to 1000° C. under an atmosphere of air or oxygen after film-forming. That is, the material for the lower electrode film **60** must retain conductivity at such high temperature and under an oxidation atmosphere. In particular, when lead zirconate titanate (PZT) is used as the piezoelectric layer **70**, it is preferable that the lower electrode film **60** changes its conductivity as little as possible by diffusion of lead oxide. Platinum is preferable due to these reasons.

Next, the piezoelectric layer **70** is formed into a film as shown in FIG. **7**(*c*). It is preferable that the crystal of this piezoelectric layer **70** is oriented. For example, in this embodiment, the piezoelectric layer having the oriented crystal is formed by use of a so-called sol-gel method. Here, the sol-gel method includes the steps of dissolving/dispersing organic metal in a solvent, coating, drying to form gel, and baking the gel at a high temperature to obtain the piezoelectric layer **70** made of metal oxide, As the material for the piezoelectric layer **70**, a material in a lead zirconate titanate group is preferred for use in an ink-jet recording device. Note that the method of film-forming this piezoelectric layer **70** is not particularly limited and the piezoelectric layer **70** may be formed by a sputtering method, for example.

In addition, it is also possible to use a method including a step of forming a lead zirconate titanate precursor film by a sol-gel method, a sputtering method or the like, and a step of growing crystal at a low temperature by a high pressure process in an aqueous alkaline solution.

In any case, the piezoelectric layer **70** thus formed has the crystal subjected to priority orientation unlike a bulk piezoelectric material. Moreover, in the present embodiment, the piezoelectric layer **70** has the crystal formed into a columnar shape. Note that the priority orientation refers to a state where the direction of orientation of the crystal is not in disorder but a specific crystal plane of the crystal is oriented approximately to a fixed direction. In addition, a thin film having a crystal in a columnar shape refers to a state of forming a thin film, in which crystals having approximately columnar shapes are gathered across the surface direction while center axes thereof are coincided approximately with the thickness direction. It is a matter of course that the piezoelectric layer **70** may be a thin film formed of particle-shaped crystals subjected to the priority orientation. Note that a thickness of a piezoelectric layer thus manufactured in the thin film process is generally in a range from 0.2 to 5 μm.

Next, the upper electrode film **80** is formed into a film as shown in FIG. **7**(*d*). It is essential only that the upper electrode film **80** is made of a highly conductive material, therefore many kinds of metal such as aluminum, gold, nickel and platinum, conductive oxides, and the like can be used. In this embodiment, platinum is formed into a film by sputtering.

Next, as shown in FIG. **7**(*e*), patterning of the piezoelectric elements **300** is performed by etching only the piezoelectric layer **70** and the upper electrode film **80**.

Next, the extraction electrodes **90** and the laminated electrode layer **95** are formed as shown in FIG. **8**(*a*). In this embodiment, a metallic film **90A** made of gold (Au) or the like to include the extraction electrodes **90**, for example, is formed on the entire surface of the passage-forming substrate **10** and then this metallic film **90A** is patterned to form the respective extraction electrodes **90** for the respective piezoelectric elements **300**. Meanwhile, in this event, the metallic film **90**A in the region opposing to the outside of the array of the pressure generating chambers **12** is left to form the laminated electrode layer **95**.

Next, as shown in FIG. **8**(*b*), the insulation layer **110** is formed around the array of the pressure generating chambers **12** and the penetrated portions **112** and **113** are formed in given positions. Specifically, after forming the insulation layer **110** on the entire surface of the passage-forming substrate **10**, the opening portion **111** (not illustrated) and the penetrated portions **112** and **113** are formed by etching to include a given pattern.

As for the material of this insulation layer **110**, it is preferable to use photosensitive resin such as polyimide. In this way, it is possible to form the insulation layer **110** relatively easily and with high accuracy. Moreover, the material for the insulation layer **110** is not particularly limited as long as the material has relatively high insulation property. For example, it is also possible to use fluorocarbon resin, silicone resin, epoxy resin, silicon oxide, silicon nitride, tantalum oxide, or the like.

Next, the connective wiring layer **120** is formed on the insulation layer **110** as shown in FIG. **8**(*c*). Specifically, after forming the connective wiring layer **120** on the entire surface of the passage-forming substrate **10**, a given pattern is formed by etching.

As described previously, this connective wiring layer **120** also functions to reduce the resistance value of the lower electrode film **60**. Accordingly, it is preferable to use metal at least having smaller resistivity than that of the lower electrode film **60**. For example, such metal includes gold (Au), copper (Cu), aluminum (Al), and the like. For example, the connective wiring layer **120** is formed by sputtering gold (Au) in this embodiment.

Here, upon forming the connective wiring layer **120**, the insulation layer **110** is removed in the vicinity of the tip portions of the extraction electrodes **90**, thereby constituting exposed portions **90***a* with exposed surfaces as shown in FIG. **9**(*a*) Therefore, patterning of the connective wiring layer **120** may simultaneously cause patterning of the exposed portions **90***a* of the extraction electrodes **90**. For this reason, upon patterning the connective wiring layer **120**, it is also possible to leave independent wiring layers **130** in regions opposing to the exposed portions **90***a* of the extraction electrodes **90** and being independent of the connective wiring layer **120** as shown in FIG. **9**(*b*).

The size of this independent wiring layer **130** is not particularly limited, however, it is preferable that the independent wiring layer **130** covers the exposed portion **90***a* and is formed into approximately the same shape as the exposed portion **90***a*. In this way, it is possible to avoid the exposed portion **90***a* of the extraction electrode **90** from removal in the event of forming the connective wiring layer **120**. In addition, it is also possible to avoid short-circuits of the respective extraction electrodes **90**.

Description has been made regarding the film-forming process as described above. After forming the films, the single crystal silicon substrate is subjected to anisotropic etching with the aqueous alkaline solution as described previously. In this way, the pressure generating chambers **12**, and the like are formed as shown in FIG. **8**(*d*).

As a matter of fact, a lot of chips are formed simultaneously on one wafer by the above-described series of film-forming process and anisotropic etching. After completion of the process, the wafer is divided into the passage-forming substrates **10** of the same chip size as shown in FIG. **1**. Thereafter, the reservoir-forming plate **30** and the compliance plate **40** are sequentially adhered to the divided passage-forming substrate **10** for integration. In this way, the ink-jet recording head is completed.

(Other Embodiments)

Although description has been made regarding one embodiment of the present invention, it is to be understood that the constitution of the present invention shall not be limited to those expressly stated above.

For example, the laminated electrode layer **95** is provided on the lower electrode film **60** in the above-described embodiment. However, it is needless to say that the laminated electrode **95** is not always necessary if the resistance value of the lower electrode film **60** is sufficiently reduced only by the connective wiring layer **120**.

For example, the opening portion **111** is provided in the region opposing to the array of the pressure generating chamber **12** of the insulation layer **110** in the above-described embodiment. However, it is needless to say that the opening portion **111** need not be provided if the insulation layer **110** has a thickness which does not prevent the displacing of the vibration plate.

Moreover, for example, the above-described embodiment has been described based on the ink-jet recording head of a thin-film type, which is manufactured by application of the film-forming and lithography processes. However, it is needless to say that the present invention is not limited to the ink-jet recording head of the thin-film type. For example, the present invention is also applicable to an ink-jet recording head of a thick-film type, which is typically formed by the process of sticking a green sheet, and the like.

Meanwhile, the ink-jet recording head of each of the embodiments includes part of a recording head unit provided with an ink-flow path that communicates with an ink cartridge and the like, and the recording head unit is loaded into an ink-jet recording apparatus. FIG. **10** is a schematic illustration showing one example of the ink-jet recording apparatus.

As shown in FIG. **10**, cartridges **2**A and **2**B are detachably provided on recording head units **1**A and **1**B having the ink-jet recording heads, respectively. A carriage **3** loading the recording head units **1**A and **1**B is disposed as movable in an axial direction on a carriage shaft **5** fitted to an apparatus body **4**. These recording head units **1**A and **1**B are designed to eject a black ink composition and a color ink composition respectively, for example.

Moreover, driving force of a driving motor **6** is transmitted to the carriage **3** via an unillustrated plurality of gears and a timing belt **7**, whereby the carriage **3** loading the recording head units **1**A and **1**B is allowed to move along the carriage shaft **5**. Meanwhile, a platen **8** is provided on the apparatus body **4** along the carriage shaft **5**, and a recording sheet S that is a recording medium such as paper fed by an unillustrated feeding roller or the like is conveyed onto the platen **8**.

As described above, according to the present invention, a common electrode of a piezoelectric element is electrically connected to a connective wiring layer. Hence, a resistance value of the common electrode is substantially reduced, and a voltage drop does not occur if many piezoelectric elements are driven simultaneously. Moreover, the common electrode is electrically connected to the connective wiring layer via a penetrated portion provided on an insulation layer. Accordingly, it is possible to form the connective wiring layer in a region opposing to the piezoelectric element.

Therefore, the present invention exerts an effect that a favorable and stable ink ejecting characteristic can be obtained without increasing the size of the head.

Moreover, though the present invention has been described while exemplifying the ink-jet recording head that ejects ink as a liquid-jet head, the present invention is aimed to widely cover the overall liquid-jet heads and liquid-jet apparatuses. As such liquid-jet heads, for example, the following can be given: a recording head for use in an image recording apparatus such as a printer; a color-material-jet head for use in manufacturing a color filter of a liquid crystal display or the like; an electrode-material-jet head for use in forming electrodes of an organic EL display, an FED (field emission display) or the like; a bio-organic-material-jet head for use in manufacturing a biochip; and the like.

What is claimed is:

1. A liquid-jet recording head having a passage-forming substrate in which pressure generating chambers to communicate with nozzle orifices is formed, and piezoelectric elements provided on one side of the passage-forming substrate through a vibration plate to generate pressure changes inside the pressure generating chambers, the liquid-jet recording head comprising:

an insulation layer which is continuously provided at least in a region opposing to the vicinity of longitudinal end portions of the piezoelectric elements along a direction of arrangement of the piezoelectric elements, the insulation layer also having penetrated portions in a region opposing to a common electrode provided in common to the plurality of piezoelectric elements; and

a connective wiring layer which is continuously provided on the insulation layer to be electrically connected to the common electrode through the penetrated portions.

2. The liquid-jet recording head according to claim **1**, wherein the penetrated portions are provided on the insulation layer in regions opposing to compartment walls partitioning the pressure generating chambers, respectively.

3. The liquid-jet recording head according to claim **1**, wherein the insulation layer in a region opposing to the pressure generating chamber is removed.

4. The liquid-jet recording head according to claim **1**,

wherein an extraction electrode which is drawn out of an individual electrode of the piezoelectric element extends to the vicinity of an end portion of the passage-forming substrate, and

at least a position close to a tip portion of the extraction electrode constitutes an exposed portion where a surface thereof is exposed by removing the insulation layer and the connective wiring layer.

5. The liquid-jet recording head according to claim **4**, wherein the exposed portion of the extraction electrode is made of the same layer as the connective wiring layer and is electrically connected to an independent wiring layer respectively, which is independent of the connective wiring layer.

6. The liquid-jet recording head according to claim **5**, wherein the exposed portion of the extraction electrode is covered with the independent wiring layer.

7. The liquid-jet recording head according to claim **4**, further comprising:

a laminated electrode layer which is provided on the common electrode in a region corresponding to outside of an array of the pressure generating chambers, the laminated electrode layer being made of the same layer as the extraction electrode and provided independently of the extraction electrode,

wherein the laminated electrode layer is electrically connected to the connective wiring layer.

8. The liquid-jet recording head according to claim **1**, wherein the insulation layer is made of photosensitive resin.

9. The liquid-jet recording head according to claim **8**, wherein the photosensitive resin is polyimide resin.

10. The liquid-jet recording head according to claim **1**, wherein the insulation layer is made of any one of fluorocarbon resin, silicone resin, epoxy resin, silicon oxide, silicon nitride, and tantalum oxide.

11. The liquid-jet recording head according to claim **1**, wherein the common electrode has a film thickness within 0.5 μm.

12. The liquid-jet recording head according to claim **1**,

wherein the pressure generating chamber is formed on a single crystal silicon substrate by anisotropic etching, and the respective layers of the piezoelectric element are formed by a film-forming method and a lithography method.

13. A liquid-jet recording apparatus comprising:

the liquid-jet recording head according to any one of claims **1** to **12**.

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